Ergastic Substances:

The nonliving cell inclusions produced as a result of metabolic activity of cell are known as ergastic substances. These substances are found in cytoplasm, vacuoles and cell walls. Some of these have great importance in plant life while others are absolutely by-products.

These substances are grouped as:
(1) Reserve material,

(2) Secretory material and

(3) Excretory material.

1. Reserve material:
The autotropic plants by photosynthesis synthesize carbohydrate that along with other metabolite forms proteins, fats and oils. These substances may be used up to make new protoplasm and to provide energy for cellular activities or may be stored as reserve food materials for future use. The reserve materials are carbohydrate, protein, oil and fats.

(A) Carbohydrate:
Carbohydrates (= carbon hydrates) are composed of carbon, hydrogen and oxygen where the ratio between the latter two is two: one. They are often referred to as saccharides (Latin, Sacchariim = sugar) because the simpler members of the carbohydrate taste sweet.

The elements of carbohydrate are obtained from atmospheric carbon dioxide and water during photosynthesis. Carbohydrates are classified into monosaccharides, oligosaccharides and polysaccharides on the basis of number of simple sugar molecule produced on hydrolysis.

i. Monosaccharide (simple sugar):
These are composed of single unit of carbohydrate. They cannot be broken into simpler carbohydrates on hydrolysis. Example: glucose (present in grape sugar), fructose (found in honey) etc. They are

also referred to as hexose as six carbon atoms are present in these sugars.

ii. Oligosaccharide:
They contain two to ten units of monosaccharide in a molecule. The oligosaccharides containing two units of monosaccharide are called disaccharide (ex. sucrose); those containing three units are called trisaccharide (ex. raffinose).

Sucrose of cane sugar yields glucose and fructose, one molecule each on hydrolysis. It is the table sugar and is extracted from sugarcane. Another disaccharide — maltose yields two molecules of glucose on hydrolysis. The trisaccharide raffinose yields glucose, fructose and galactose on hydrolysis.

iii. Polysaccharide:
Each molecule of polysaccharide is made up of more than ten units of monosaccharide. These include the storage polysaccharide and the structural polysaccharide inulin, starch, cellulose, pectin etc.

(a) Inulin:
This polysaccharide yields only fructose on hydrolysis. It is found as a storage material in some members of Asteraceae (tuber of Dahlia, Helianthus tuberosus), Campanulaceae and monocotyledons. Inulin is spherical or star shaped crystal. Incompletely formed crystals can be seen as fan-shaped structure.

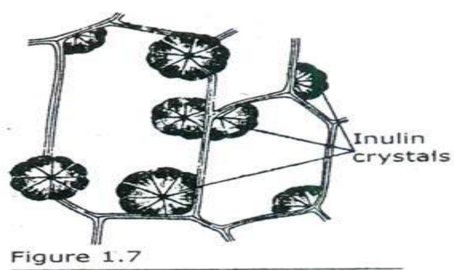


Figure 1.7
Cells from root-tuber of *Dahlia* with inulin crystals.

(b) Starch:
The glucose units are the building blocks of this insoluble polysaccharide. They are found in all parenchymatous tissues mainly in storage organs like rhizomes, endosperm, corms, tubers,

cotyledon of seeds etc. They are also present in latex tubes of stems and roots, endodermis, seeds of cereal, grains of rice, wheat, maize etc.

The assimilatory starch, a temporary product is synthesized by the chloroplasts. This temporary starch is subsequently broken down to sugar that is transported to the storage organs where storage starch is synthesized by amyloplast.

Starch appears in the form of grains that stain bluish black with potassium iodide solution. Each starch grain consists of a centre, called hilum that is the centre of origin of the grain. Carbohydrates are deposited in layers around the hilum. This gives starch grain a striated appearance. The deposition of layers depends upon endogenous rhythms.

In cereals, single layer is deposited in a day, i.e. the number of striations denotes the number of days' growth. The hilum may be centrally situated as in concentric grains where carbohydrates are laid down concentrically around the hilum (e.g. Triticum durum) or the hilum may be eccentric as in case of eccentric grains where the layers of carbohydrates are deposited on one side of hilum (ex. Solarium tuberosum) .

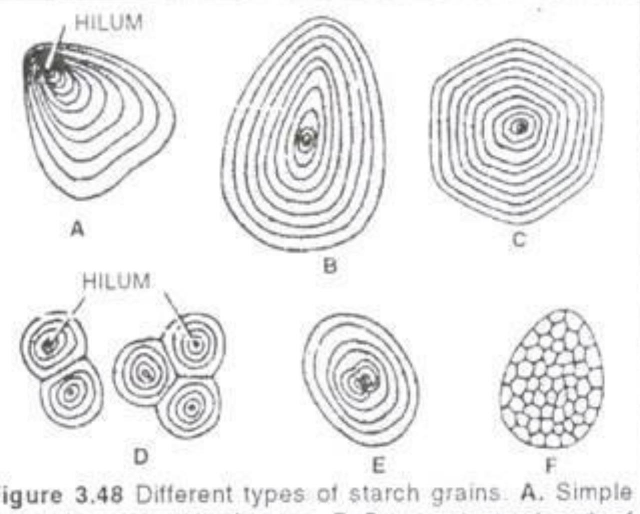


Figure 3.48 Different types of starch grains. **A.** Simple eccentric starch grain of potato, **B.** Concentric starch grain of wheat, **C.** Concentric starch grain of maize, **D.** Compound starch grain of banana, **E.** Semicompound starch grain of potato, **F.** Compound starch grain of oat.

Starch grains may be classified as simple, semi-compound or half-compound and compound. In simple type each grain remains singly with solitary hilum whereas in compound type two or more grains are aggregated together (ex. Oryza sativa, Ipomoea batatas, Avena sativa) with their separate hila.

The half compound grains (e.g. potato) consist of two hila with their lines of stratification aggregated together around which several common layers of carbohydrate are present.

Starch grains vary in shapes, sizes, position of hilum, solitary or in aggregates and in general appearance. Their extensive morphological variations make it possible to identify starch containing plant species.

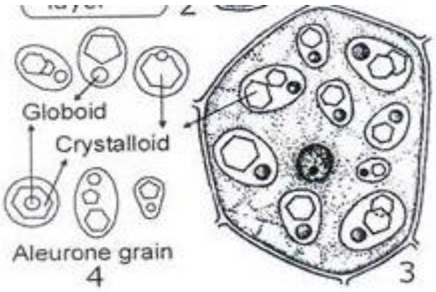
(c) Cellulose:
This insoluble structural polysaccharide is the major constituent of cell wall of higher plants. The building blocks of cellulose are glucose units that are held together by β (1-4) linkages. In cellulose molecule approximately 15,000 molecules of glucose residues are present.

(d) Pectin:
This structural polysaccharide is chiefly present in the middle lamella and primary walls of dicots. Pectins are rich in galacturonic acid, rhamnose, arabinose and galactose.

(B) Protein:
Proteins are composed of amino acids that are linked by peptide bonds. They are one of the vital ingredients of living protoplasmic bodies. They sometimes occur as structural proteins of cell wall and storage proteins. Storage protein may be in the form of definitive bodies called aleurone grains or they may be amorphous or crystalline.

Amorphous protein is found in the aleurone layer (the outermost layer of endosperm) of Triticum. Crystalline protein possesses both crystalline and colloidal properties. So these crystalline proteins are referred to as crystalloids. Proteins, in the form of cuboidal crystalloids are observed in the peripheral parenchyma cells of potato tuber and in the fruit of Capsicum.

Aleurone grains are bounded by a proteinaceous membrane. The membrane may enclose amorphous protein, globoids, and crystalloids (e.g. Myristica fragrans) or crystals of calcium oxalate (Umbelliferae). The aleurone grains of Ricinus usually contain one globoid and one crystalloid, bounded by a single membrane.



(C) Oil and fat:
They are the glycerides of fatty acid. The oils are liquid and the fats are solid at normal temperature. In contrast to protein and carbohydrate they provide more calories and so they are valuable reserve food materials. They are abundant in the cells of endosperm or perisperm of seed, fruits, spores, embryos, and meristematic cells and in differentiated tissues of vegetative body.

They occur also in the cytoplasm of cell sap as dispersed or aggregated large masses. They are produced either by elaioplast or spherosomes. The essential or volatile oils may occur in all tissues (e.g. Conifers), in petals of roses, in the fruit skin of orange, in the special layer (i.e. second layer below the epidermis) of Elettaria cardamomum seed.

Specialized secretory tissues produce these essential oils. Wax, cutin and suberin are other fatty substances, which usually form a protective covering of the epidermal cell walls. Oils and fats stain a reddish colour when treated with Sudan III or IV.

2. Secretory material:
These substances, though not concerned with nutrition are valuable ergastic substances. They are produced during plant metabolism and perform specific roles in plant life.

These include:
(i) Colouring matter,

(ii) Enzyme and

(iii) Nectar.

i. Colouring matter:
Leaves, petals and fruits of a plant exhibit various colours. This is due to the pigment present in the cell. The leaves and aerial organs possess chlorophyll that imparts green colours to them. This pigment is responsible for the phenomenon-photosynthesis. The other pigment carotenoids, i.e. carotene and xanthophyll impart orange to yellow colour of many flowers and fruits.

The red, blue, violet and pink colour is due to anthocyanin-the water-soluble pigment. Due to the presence of carotenoids and anthocyanins, flowers and fruits become brightly coloured. As a result they attract agents to bring about pollination and fruit dispersal, which are the vital phenomenon in plant life.

ii. Enzyme:
Enzymes are regarded as 'biological catalyst' that catalyzes all the chemical reactions that occur in a plant cell. In a metabolic cell there are many metabolic pathways of different metabolisms like carbohydrate metabolism, protein metabolism, fat metabolism etc. Enzymes catalyze every step of chemical reactions of these pathways. Example: zymase, lipase, protease, invertase, diastase etc.

iii. Nectar:
Nectar is produced and secreted by the nectar secreting glands called nectaries that are present in flowers. Nectars are mainly composed of glucose, fructose and sucrose. Insects are attracted to flowers for obtaining nectar. Insects during their visit carry pollen grains from one flower to another and thus pollination is effected in entomogenous flowers.

3. Excretory material:

These ergastic substances are the by-products of plant metabolisms and are of no use to the plants. These waste materials remain stored in the dead cells. Plants do not possess any excretory system. They get rid of some of the excretory or waste materials through fall of leaves, fruits, seeds, barks etc.

A few important excretory materials are mentioned below:

(a) Alkaloids:

These are nitrogenous waste substances and are found in roots, leaves, barks, seeds and other parts. Example: quinine occurs in the bark of Cinchona, morphine is present in the fruit of opium poppy (Palaver somniferum), atropine in the leaves of Atropa belladonna etc.

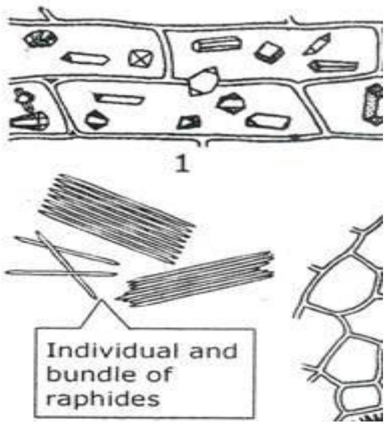
(b) Crystals:

These are the depositions of waste products within a cell. They are composed of either calcium carbonate or calcium oxalate, which is more common. The crystal-containing cell may be similar to neighbouring cell that lack crystals or it may be easily distinguished from the other cells by their shape and size.

This special crystal-containing cell is termed as idioblast. Crystals originate within vacuoles. Crystals may remain single or as aggregate in the cell. Sometimes a large crystal is present filling up the entire cell cavity. Usually they lie loose in the cells, but some are found to be suspended from the cell wall.

i. Crystals of calcium oxalate:

They appear in definite forms that are as follows



Prism:
It is rectangular or pyramidal in shape and occurs single or as twin prisms. Example: leaves of Citrus, Begonia etc.

Druse:
It is more or less spheroidal in shape. Many prism or pyramidal crystals aggregate to form a druse. In these crystal-aggregates some projecting points are observed all over the surface. Druse is also known as sphere-crystal or sphaeraphide. They are found in the leaves of Datura, Nerium, petiole of Carica etc.

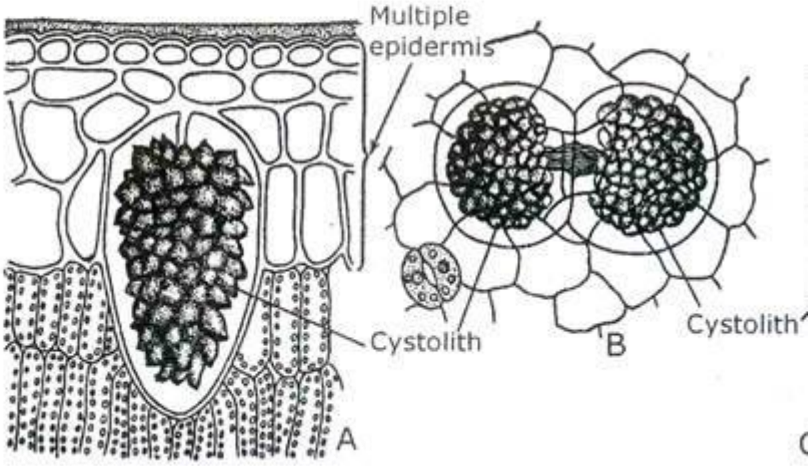
Raphide:
It is thin elongated needle shaped or acicular crystal that is tapered at both ends to a tip point. It usually occurs as aggregate bundles in idioblast, which is much larger than the neighbouring cells. Raphides are found in the petals of Impatiens, leaves of Colocasia, leaves of pistia, etc. The raphide containing cells may contain mucilage.

Rosette:
In Umbelliferae, the aleurone grains in seeds contain rosette crystals. The crystals are large with equal lengths. They deposit around a centre along the radius in all directions to from rosette.

Crystals of calcium carbonate:
These crystals are known as cystolith and are found in parenchyma, epidermal cells, trichomes or hairs (e.g. Humulus lupulus) and in the leaves of Acanthaceae, Urticaceae, Cucurbitaceae etc. A cell may contain solitary or more than one crystal. The leaf of Momordica

contains double cystolith. The epidermal cell containing cystolith is known as lithocyst.

In the leaf of Ficus elastica, the lithocyst that contains the solitary cystolith is much larger than other epidermal cells. In the lithocyst a stalk made up of cellulose develops and projects into the cell lumen. Calcium carbonate deposits around the stalk and fully developed cystolith appears as grape-like clusters with a stalk that is attached to the cell wall from where it hangs into the cell lumen.



During development all epidermal cells have similar appearance. Later, cells destined to become lithocyst can be differentiated by their large nucleus and denser cytoplasm. The cells do not divide along with neighbouring cells, only enlarge and become lithocyst where the nucleus appears to remain functional.

(c) Essential oils or volatile oil:

The odoriferous organs of a plant contain essential oils. They are produced in special cells or glands. They occur in flowers, leaves, and fruits etc. Mention may be made of oil of peppermint from Mentha piperita, clove oil obtained form Eugenia caryophyllata, eucalyptus oil found in Eucalyptus globulus etc. Though volatile oils are excretory products, yet they have the biological significance to attract vectors to bring about pollination and dispersal of seed and fruits.

(d) Glycosides:

They are composed of glucose and some other substances, e.g. sinigrin —sulphur-containing glycoside present in Brassica nigra, digitogenin present in Digitalis purpurea etc.

(e) Gum:
Gums are exudes in the form of thick juice from the bark. The cellulose of cell wall by decomposition forms gums. Usually gums are exuded naturally, but sometimes they are exuded in response to injuries to heal up the wounds. The gum arabic of commerce is obtained from Acacia Senegal. It is used in medicine, confectionery and sizing and finishing materials in textile industry.

(f) Latex:
Latex is a fluid secreted by special group of cells termed laticifers. They are present in the families Asclepiadaceae, Apocynaceae, Moraceae, and Euphorbiaceae etc.

Latex may be colourless or coloured as milky white or yellow to orange. It consists of carbohydrate, alkaloids, organic acids, oils, resins, rubber, starch etc. Papain, the proteolytic enzyme is present in the latex of Carica papaya. The alkaloid opium is rich in the latex of Papaver somniferum; Hevea brasiliensis, a member of Euphorbiaceae, yields about 2240 kg rubber per hectare annually.

(g) Organic acid:
Different kinds of organic acids are found in plants and some of them remain concentrated in leaves and fruits. These are produced during different types of metabolisms. Some common acids are tartaric acid — found in tamarind, malic acid present in apple, citric acid in oranges etc.

(h) Resin:
These may be solid, brittle or liquid in nature with complex chemical composition. They are produced in special gland or secretory cells present surrounding the resin ducts. Most of the coniferous trees are rich in resins. The resin Canada balsam is obtained from the conifer Abies balsamea.

(i) Tannins:

These are non-nitrogenous phenol derivatives and present in cell sap. They may be yellow, red or brown and appear as granules in a cell. Tannins are found in seed coats, in unripe fruits, in leaves and in the tissues infected by pathogens. Tannins are also present in periderm and heartwood; as a result they become hard. The presence of tannin prevents pathogenic attack. Tannins are used in medicine, in leather industry, in dye industry etc.